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EXPERIMENTAL STUDY ON THE MIX PROPORTIONS OF HIGH STRENGTH CONCRETE

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Bachelor of Engineering with Honours
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ABD. RAHMAN BIN HASHIM

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Dedicated to my beloved family, friends and honey

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ABSTRACT

The results of an experimental study on the mix proportions of high strength concrete are presented. Materials used to form high strength concrete mixture were fly ash and superplasticizer as admixture to help the concrete gain the strength needed. The fly ash content was 10% by mass of the total cementitious material. The total cement content selected were 450, 500, and 550 kg/m^3 for different types of HSC. The coarse aggregate used was 10 mm crushed granite with an amount of 60% by weight of total aggregate in concrete. The water/binder ratio equal to 0.30 was chosen. Flow tests were conducted to measure the workability of the concrete and also to determine the suitable dosage of superplasticizer. The workability of 24 cm flow was fixed for every mix proportions. Slump tests were conducted mainly to see the uniformity of the concrete, but not to measure the workability of the concrete. Finally, the compression tests for concrete cube and concrete cylinder were performed to determine the compressive strength of the concrete. The experimental results show that every of the designed mix proportions were achieved the required strength of high strength concrete of higher than 41 MPa.

ABSTRAK

Keputusan-keputusan ujikaji ke atas nisbah campuran konkrit berkekuatan tinggi telah ditunjukkan. Bahan-bahan yang telah digunakan untuk menghasilkan adunan konkrit berkekuatan tinggi ialah fly ash dan superplasticizer sebagai bahan tambahan untuk membantu konkrit mencapai kekuatan yang diperlukan. Kandungan fly ash adalah 10% daripada berat keseluruhan bahan pengikat. Jumlah keseluruhan simen yang telah dipilih ialah 450, 500, dan 550 kg/m^3 untuk jenis HSC yang berlainan. Batu kasar yang telah digunakan adalah 10 mm granite hancur dengan jumlah 60% daripada jumlah keseluruhan batu di dalam konkrit. Nisbah air/pengikat yang telah dipilih ialah 0.3. Ujian-ujian kebolehaliran telah dijalankan untuk mengukur tahap kebolehkerjaan dan juga untuk menentukan dos yang sesuai bagi superplasticizer. Kebolehkerjaan 24 cm kebolehaliran telah ditetapkan untuk setiap nisbah campuran. Ujian-ujian penurunan telah dilakukan untuk melihat keseragaman campuran konkrit, tetapi bukan untuk mengukur tahap kebolehkerjaan konkrit. Akhir sekali, ujian-ujian mampatan untuk konkrit kiub dan konkrit silinder telah dijalankan untuk menentukan kekuatan mampatan konkrit. Keputusan-keputusan ujikaji menunjukkan bahawa setiap nisbah campuran yang telah direkabentuk telah mencapai kekuatan yang diperlukan oleh konkrit berkekuatan tinggi melebihi 41 MPa.

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SECTION 1

INTRODUCTION AND SCOPE OF STUDY

1.1 INTRODUCTION

The purpose of this project was to investigate the mix proportion of high strength concrete (HSC) with the addition of mineral and chemical admixtures such as fly ash (FA) and superplasticizer (SP), respectively. The compressive strength tests were conducted in order to get the specific strength of HSC. The main interests of the study were to design the mix proportions of HSC and determine the optimum compressive strength of HSC with different levels of cement contents.

1.2 BACKGROUND

In recent years there has been a rapid growth of interest in HSC. Although, the exact definition arbitrary, the term generally refers to concrete having uniaxial compressive strength in the range of about 41 to 82 MPa (6000 to 12 000 psi) or higher. Such concretes can be made using carefully selected but widely available cements, sands, and stone; certain admixtures including high-range water reducing or SP, FA, and silica fume; plus very careful quality control during production. In addition to higher strength in compression, most other engineering properties are improved, leading to use of the alternative term high performance concrete (Ramakrishnan, 1993).

HSC is defined by the American Concrete Institute (ACI) as concrete with a specified compressive strength of 41 MPa (6,000 psi) or greater. Although concretes with compressive strengths greater than 41 MPa (6,000 psi) can be produced using only cement as the binding material, it is likely that these concretes will also contain a mineral admixture such as FA, silica fume, or ground granulated blast furnace slag (GGBFS) (Russell, 2000).

The major difference between conventional concrete and HSC is essentially the use of chemical and mineral admixtures. Use of chemical admixtures reduces the water content, thereby reducing the porosity within the hydrated cement paste. The reduction in water content to a very low value with high dosage of chemical admixtures is undesirable and the effectiveness of chemical admixtures such as superplasticizer (SP) principally depends on the ambient temperature, cement chemistry and fineness. Mineral admixtures, also called as cement replacement materials (CRM), act as pozzolanic materials as well as fine fillers, thereby the microstructure of hardened cement matrix becomes denser and stronger. At ambient temperature their chemical reaction with calcium hydroxide is generally slow. However, the finer and more vitreous the pozzolana is, the faster will be this reaction. If durability is of primary interest, then the slow rate of setting and hardening associated with the incorporation of FA or slag in concrete is advantageous. Also, the mineral admixtures are generally industrial by-products and their use can provide a major economic benefit. Thus, the combined use of SP and CRM can lead to economical HSC with enhanced durability. It is also reported that the concrete containing CRM typically provides lower permeability, reduced heat of hydration, reduced alkali-aggregate reaction, higher strength at later ages and increased resistance to attack from sulfates. However, the effect of a CRM on the strength of concrete varies markedly with their properties. Fly ashes are the most variable and least reactive of all CRMs and should be used with care and not on basis of any generalization. It is also not known at present what factor can maximise the fly ash contribution (Bharatkumar et al., 2000).

The workability of HSC is mainly evaluated by the slump test or the flow test. An alternative test method adopted in Japan and Taiwan is the slump-flow test, which is simply a measurement of the diameter of the concrete after it has collapsed in a standard slump test. However, the validity of a slump test is generally recommended for concrete with a slump value ranging from 25 to 175 mm, corresponding approximately to a consistency ranges from low plastic to medium plastic stage. Therefore, these test methods do not seem appropriate to characterize the workability of HSC with high flowability, since its slump value is usually more than 200 mm. Moreover, it is practically known that concretes with the same slump value or flow value may have different workability. To evaluate the rheological property solely based on these test results can possibly be misleading (Tsong Yen et al., 1998).

The use of HSC has advantages in the precast and prestressed concrete industries, where it can result in a more rapid output of components and less product loss during handling. In high-rise construction, advantage can be taken of reduced dead load, which allows thinner concrete sections and longer beams spans. Advantage of HSC is that it behaves in a more brittle fashion. It must be remembered that the task of obtaining high early strengths (1 to 28 days or later) is quite a different problem. It is true that HSC will show somewhat higher strengths even as early as 1 day, but even in the 28-day strength. The biggest single factor affecting strength is the porosity of the concrete, which is controlled primarily by the w/c ratio of the paste, although consolidation methods also play a part. HSC fail in a more brittle fashion because the paste-aggregate bond is also strengthened. Much less progressive microcracking occurs on loading and failure passes through both aggregate and paste (Mindness and Young, 1981).

The most common application of HSC has been in the columns of tall concrete buildings, where normal concrete would result in unacceptably large cross sections, with loss of valuable floor space. It has been shown that the use of the more expensive HSC mixes in columns not only saves floor area but is more economical than increasing the amount of steel reinforcement. For example, concrete of up to 82 MPa (12,000 psi) was specified for the lower-story column of 311 South Wacker Drive in Chicago, having a total height of 293.8 m (964 ft) (Nilson and Winter, 1991).

1.3 AIMS AND OBJECTIVES

The aims of the present study were to investigate the mix proportions of HSC with different level of cement contents, and the suitability of the dosage of SP used in the mix proportions design of HSC with FA. In accordance with the aims of the study, the main objectives were as follows:

1. To conduct a series of flow test, to determine the required dosage of SP.
2. To conduct a series of cube and cylinder compression tests, to determine the compressive strength in about 41 MPa or higher.

1.4 OUTLINE OF PROJECT REPORT

Section 2 provides a review on the mix proportions of HSC, trial mixtures in HSC, and new development in HSC.

Section 3 presents the methods and procedures of experimental investigation, which includes selection of materials, preparation of test specimens, testing for workability, and compression tests for concrete cubes and cylinders.

Section 4 describes the experimental results and discussion, which consists of flow test results, slump test results, cube compression test results, and cylinder compression test results.

Section 5 contains conclusions of the project and also the recommendations for future study.

SECTION 2

LITERATURE REVIEW

2.1 GENERAL

This section provides review regarding to the mix proportions of HSC, and are divided into four major parts. The first part discuss about the materials use in the mix proportion HSC. This part consists of the Portland cement, water and air, water/cement and water binder ratio, aggregates, and also the admixtures, use in the production of HSC. The second part includes about the trial mixtures in proportioning of HSC and also provided the examples and results of HSC. Besides that this section also provides review and study about the new development in HSC and also the summary for this section in the later part.

2.2 MIX PROPORTIONS OF HIGH STRENGTH CONCRETE

2.2.1 Portland cement

There are wide varieties of cements that are used to some extent in the construction and building industries, or to solve special engineering problems. The chemical compositions of these cements can be quite diverse, but by far the greatest amount of concrete used today is made with Portland cements. This part will therefore discuss the composition of Portland cements in considerable detail.

Portland cement is the proper selection of the type and source of cement is one of the most important steps in the production of HSC. Variation in the chemical composition and physical properties of the cement affect the concrete compressive strength more than variations in any other single material. There is also optimum cement content beyond which little or no additional increase in strength is achieved by increasing the cement content. It is necessary to include other materials such as FA, silica fume, or combinations of these materials to achieve higher strengths (Russell, 2000).

Portland cement was first made in Portland, England, from which it derived its name by Joseph Aspdin in 1824. Either a wet or a dry process can produce Portland cement. In the wet method, the raw materials are blended and ground in a slurry condition. In the dry process, operations are carried out with the materials in a dry state. The addition of clay or stone of known characteristics makes adjustments to the constituents. Portland cement is obtained from finely pulverizing clinker produced by calcining to incipient properly proportioned argillaceous and calcareous materials. The final constituents and properties of Portland cement are very carefully controlled during the manufacture (Kett, 2000).

Portland cement is hydraulic cement that hardens by interacting with water and forms a water-resisting compound when it receives its final set. Compared with nonhydraulic cements such as gypsum and lime, which absorb water after hardening, Portland cement is made of finely powdered crystalline materials composed primarily of calcium and aluminum silicates. The addition of water to these minerals produces paste which, when hardened, becomes of stonelike strength. Its specific gravity ranges between 3.12 and 3.16 and it weighs 14.8 kN/m^3 (94 lb/ft^3), which is the unit weight of a commercial sack or bag of cement.

Its fineness measured by particle size can range between 10 and 50 μm (Roy and Silsbee, 1994).

In principle, the manufacture of Portland cement is very simple and relies on the use of abundant raw materials. An intimate mixture, usually of limestone and clay, is heated in a kiln to 1400 to 1600°C (2550 to 2900°F), which is the temperature range in which the two materials interact chemically to form the calcium silicates. In practice, because of the large amounts of material being processed and the high temperatures required, considerable attention must be paid to the various stages of processing (see Figure 2.1) if adequate quality control is to be maintained (Mindness and Young, 1981).

Neville (2002) listed a list of different Portland cements, with or without other cementitious materials, together with the American description according to ASTM Standards C 150-94 or C 595-94a, where available, is given in Table 2.1 The former ASTM composition limits for some of these cements have listed in Table 2.2 and the main compounds of Portland cement also been listed at Table 2.3. Many of the cements have been developed to ensure good durability of concrete under a variety of conditions. It has not been possible, however, to find in the composition of cement a complete answer to the problem of durability of concrete: the principle mechanical properties of hardened concrete, such as strength, shrinkage, permeability, resistance to weathering, and creep, are affected also by factors other than cement composition, although this determines to a large degree the rate of gain of strength.

2.2.2 Water and air

Water is required in the production of concrete in order to precipitate chemical reaction with the cement, to wet the aggregate, and to lubricate the mixture for easy workability. Normally, drinking water is used in mixing. Water having harmful ingredients, contamination, silt, oil, sugar, or chemicals is destructive to the strength and setting properties of cement. It can disrupt the affinity between the aggregate and the cement paste and can adversely affect the workability of a mixture. Additionally, gradual evaporation of excess water from the concrete mixture results in pores produced in the hardened concrete. If the pores are evenly distributed, they could give improved characteristics to the product. Air entrainment increases workability, decreases density, increases durability and frost resistance, reduces bleeding and segregation, and reduces the required sand content in the mixture. For these reasons, the percentage of entrained air should be kept at the required optimum values for the desired performance quality of the concrete. The optimum air content is 6 to 9% of the mortar fraction of the concrete. Air entrainment in excess of 5 to 6% of the total mixture reduces the concrete strength proportionally (Nawy, 2001).

The water used for concrete should be clean and free from dirt or organic matter. Water containing even small quantities of acid can have a serious deleterious effect upon concrete. The presence of oil will result in slowing the set and reducing strength. Generally speaking, if water is potable, it is satisfactory for the production of a good concrete (Kett, 2000).

There is some disagreement as to the need for air entrainment of high-strength concrete. The greater strength will improve the inherent frost resistance